Depth and substrate type driven patterns in the infralittoral fish assemblage of the NW Mediterranean Sea

by

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ABSTRACT. - Fish fauna was studied in the coastal area of Portofino Promontory (Ligurian Sea) by means of visual census techniques to explore the relationships between fish assemblage, depth and substrate type. Because of the complexity of substrate types (*Posidonia oceanica*, rocky bottom, pebble, sand) and depth ranges (0-3; 3.1-12; 12.1-24 m), two different visual census methods were used. Sampling was carried out between 1998 and 1999. The data showed that species richness was greater at shallower depths and positively related with the structural complexity of the substrate type. Data analysis indicated a strong affinity between fish assemblages associated with pebble, *P. oceanica* meadow and rocky bottom, and confirmed the difference between ichthyofauna from sand and other substrate types. Depth was the main factor affecting variability in fish assemblages associated to *P. oceanica*, pebble and rocky bottom. The medium size class of fish was generally predominant in all depth and substrate type, except for the shallower depth range over sand and the deeper depth range over rocky bottom, where succeed respectively small and large size classes. The strong evidence of the role of depth and substrate should be taken into consideration in planning future studies to characterise fish assemblages in other Italian and Mediterranean coastal areas.

RÉSUMÉ. - Influences de la profondeur et du type de substrat sur la distribution des peuplements de poissons dans l'infralittoral de la mer Méditerranée nord occidentale.

L'ichtyofaune de la région côtière du promontoire de Portofino (mer Ligure) a été étudiée à l'aide de techniques visuelles afin d'étudier les liens entre les peuplements de poissons, la profondeur et le type de substrat. Une stratégie d'échantillonnage spécifique a été élaborée suivant deux méthodes de recensement en raison de la diversité des types de substrats (*Posidonia oceanica*, fonds rocheux, galets, sable) et de la profondeur (0-3 ; 3,1-12 ; 12,1-24 m). L'échantillonnage a été effectué entre 1998 et 1999. Les données recueillies montrent que la richesse en espèces est plus importante pour de faibles profondeurs et que l'abondance est corrélée positivement avec la complexité structurale du substrat. L'analyse des données a montré une forte affinité entre l'ichtyofaune associée aux galets, aux herbiers de *P. oceanica*, et aux fonds rocheux. À l'inverse, il existe une différence entre l'ichtyofaune associée au sable et celle des autres substrats. La profondeur a été le facteur principal affectant la variabilité de la faune ichtyologique associée à *P. oceanica*, aux galets et aux fonds rocheux. Les données collectées montrent une dominance générale des poissons de taille moyenne. Les analyses effectuées démontrent également qu'il y a un fort pourcentage de petits poissons à des profondeurs de 0-3 m, sur les fonds sableux ou sur les galets. L'évidence du rôle que joue la profondeur et le substrat devrait être prise en compte dans de futures études pour caractériser l'ichtyofaune d'autres secteurs côtiers italiens et méditerranéens.

Key words. - Fish assemblage - MED - Ligurian Sea - Substrate type - Depth - Visual census.

The hypothesis of recent changes in biodiversity in the Mediterranean Sea (Francour *et al*., 1994; Bianchi and Morri, 2000) stresses the importance of accurately describing the composition of local specific assemblages to identify and monitor such variations. In particular, Mediterranean fish communities seem sensitive to hydro-climatic modifications, as indicated by the increase in new immigrant species and by the extension of the geographical distribution of thermophilic species during the past few decades (Quignard and Tomasini, 2000). The monitoring of these phenomena is dependent on the development of methodological approaches that provide data on fish assemblages in reference to specific environmental features that may characterise coastal fish composition.

Many factors can influence the composition of coastal fish assemblages. In the infralittoral zone abiotic factors such as temperature, salinity and light change more rapidly than in deeper waters (Pérès, 1967). Consequently, fish assemblage composition may change strongly in relation to depth (Bell, 1983).

The relationship between fish and substrate type in temperate seas has been studied by comparing vegetated inshore areas and nearby bare substrata (Pollard, 1984; Rosaz and Odum, 1988; West and King, 1996), and describing the fish assemblages on rocky reefs (Thorman, 1986; Choat and Ayling, 1987; Falcon *et al*., 1996). Many Mediterranean studies highlight the role of substrate, specifically *Posidonia oceanica* meadows (Bell and Harmelin-Vivien, 1982; Francour, 1997, 2000) and rocky bottom (Bell, 1983; Harmelin, 1987; Dufour *et al*., 1995), in determining fish community

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composition. Over the last decade few studies in the Mediterranean have been carried out with the purpose of assessing differences in terms of abundance and species richness of fish assemblages over vegetated habitats and adjacent bare substrata. In particular, data gathered focused on a particular life history stage such as juveniles (Garcia-Rubies and MacPherson, 1995), and to evaluate the role of substrate in determine fish community compositions (Garcia-Charton and Pérez-Ruzafa, 1998; Guidetti, 2000; Letourneur *et al*., 2003).

The aims of this study were (1) to describe the structure of the infralittoral fish assemblage of the coastal area of the Portofino Promontory, (2) to analyse the relationship among species distribution, fish density, size composition, depth and substrate type, and (3) to evaluate a sampling methodology developed to collect more complete information on fish assemblages, taking into account the main aspects affecting the distribution of fish in the coastal marine ecosystems.

MATERIALS AND METHODS

Sampling activities were carried out in the coastal area of the Portofino Promontory (Fig. 1). Data on coastal fish assemblages were recorded by means of two visual census techniques, chosen due to the high heterogeneity of the benthic assemblages in the area (Morri *et al*., 1986): 1) stationary visual census (hereafter called SVC), carried out within a radius of 5 m (78.5 m^2) (Tunesi and Vacchi, 1993), to collect quantitative data (Harmelin-Vivien *et al*., 1985; Bohnsack and Bannerot, 1986); 2) random swim technique (hereafter called RST), performed at 15 minute intervals were specifically devoted to recording qualitative data on cryptic (Brock, 1982) and rare species, to estimate species richness more accurately (Jones and Thompson, 1978).

SVCs and RSTs were allocated on a stratified-random basis. Twelve strata were considered: three depth ranges (0-3 ; 3.1-12 ; 12.1-24 m), identified as relevant on the basis of previous studies (Tunesi and Salvati, 2002), and four substrate types (*Posidonia oceanica* meadows, rocky bottom, sand, pebble). The sampling activity was planned to collect a set of data for each identified stratum, avoiding the border zone, to prevent the so-called "border effect" (Connolly, 1994), where there can be increased abundances of some fish species, many of which are not specifically associated to a particular substrate type. Sampling activity was carried out three times. Three replicates of SVC were conducted *per* stratum and *per* time. The number of fish was estimated by classes of numerical abundance (1; 2-5; 6-10; 11-30; 31-50; 51-100; >100) (Harmelin-Vivien *et al*., 1985), and three classes of body length (small, medium, large), were estimated according to the maximum total length for each species (Fischer *et al*., 1987).

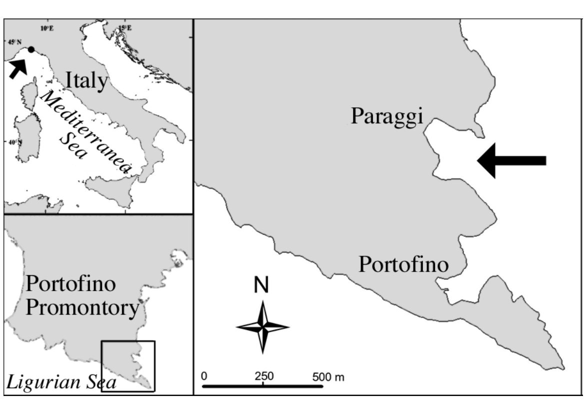

Figure 1. - Map of the study area. *[Carte du secteur d'étude.]*

Species richness *per* depth and substrate type was evaluated as total number of species (considering both data resulting from SVCs and RSTs). Fish diversity was assessed using the Shannon-Weaver Index: $H' = \sum (p_i \ln p_i)$, where p_i is the proportion of all individuals belonging to *i* species (Ludwig and Reynolds, 1988), using the mean abundance of each species obtained by SVC.

Density data were processed both for the whole assemblage and excluding the gregarious planktivorous species (*Atherina* spp., *Boops boops, Chromis chromis, Engraulis encrasicholus* and *Spicara maena*) that, because their high variability, could reduce statistic power (Guidetti, 2000).

Analysis of variance (two-way ANOVA) was performed to assess differences in Shannon-Weaver Index and in mean fish abundance *per* substrate and depth (both for the whole assemblage and excluding the gregarious planktivorous species). Density data were transformed to log (x + 1) as necessary, and data were tested for normality (Kolmogorov-Smirnov test) and homogeneity of variances (Cochran's test). Tukey test was used for post-hoc comparison after ANOVA.

Correspondence Analysis (CA) on mean abundance data was performed to identify the main factors affecting the quantitative distribution of fish assemblages. Lebart's tables (1975) were used to evaluate axis significance. Data about proportions of the different sizes of fish for each identified stratum were compared by χ^2 test.

RESULTS

Species richness

A total of 185 censuses were conducted and 68 fish taxa belonging to 22 families were recorded (Tab. I). Six families occurred with a high number of species: Sparidae (14 species), Labridae (13), Blenniidae (10), Gobiidae (6), Serranidae (4), and Scorpaenidae (3). Sixty-five species were recorded using RSTs and 52 using SVCs (Tab. I). Thirty-six species (53.0%) were registered along the entire depth range

(0 to 24 m), while 16 species (23.5%) were exclusively found in a single depth range, and 16 (23.5%) in two depth ranges (Tab. I). In particular, the highest number of exclusive species (11) were recorded in the 0-3 m depth range: between them, 8 belonged to Blennidae. Only 19 species were registered over all the substrate types. The richest fish assemblage, composed of 57 species (14 exclusive), were recorded over rocky bottom. Forty three species were registered over pebble, 36 over sand (11 exclusive), and 33 over *P. oceanica* (Tab. I). The two fish assemblages sharing the highest number of species (40) were associated to rocky bottom and pebble (Tab. II).

Table I. - Recorded fish taxa in the study area. P = pebble; Po = *P. oceanica*; R = rocky; S = sand; RST = random swim; SVC = stationary census. *[Liste des poissons observés dans le secteur d'étude : P = galets ; Po =* P. oceanica *; R = roche ; S = sable ; RST = parcours aléatoire ; SVC = points fixes.]*

Family	Taxa	Substrate types	Depth range (m)	Visual Census Method
Atherinidae	*Atherina* spp.	P-Po-R	0-12	RST/SVC
Apogonidae	*Apogon imberbis* (Linnaeus, 1758)	P-Po-R	3.1-24	RST/SVC
Blenniidae	*Aidablennius sphynx* (Valenciennes, 1836)	P-R	0-3	RST
	Coryphoblennius galerita (Linnaeus, 1758)	R	0-3	RST
	Lipophrys canevai (Vinciguerra, 1880)	R	0-3	RST
	Lipophrys nigriceps (Vinciguerra,1883)	R	0-3	RST
	Lipophrys trigloides (Valenciennes, 1836)	R	0-3	RST
	Parablennius gattoruggine (Brünnich,1768)	R	0-3	SVC
	Parablennius rouxi (Cocco, 1833)	P-R	0-24	RST/SVC
	Parablennius sanguinolentus (Pallas, 1811)	P-Po-R-S	0-12	RST/SVC
	Parablennius tentacularis (Brünnich, 1768)	R	0-3	RST
	Parablennius zvonimiri (Kolombatovich, 1892)	R	0-3	RST
Bothidae	*Bothus podas* Delaroche, 1809	S	0-24	RST/SVC
Callyonimidae	*Callyonimus pusillus* Delaroche, 1809	S	0-3	RST
Centracanthidae	*Spicara maena* (Linnaeus, 1758)	P-Po-R-S	0-24	RST/SVC
Engraulidae	*Engraulis encrasicholus* Linnaeus, 1758	S	0-12	RST/SVC
Gobiidae	*Gobius bucchichi* Steindachner, 1870	P-R-S	0-12	RST/SVC
	Gobius cobitis (Pallas, 1811)	R	0-3	RST/SVC
	Gobius cruentatus (Gmelin, 1789)	R	12.1-24	RST
	Gobius geniporus Valenciennes, 1837	R-P	0-12	RST/SVC
	Gobius vittatus Vinciguerra, 1883	R	12.1-24	SVC
	Gobius sp.	S-R	0-24	RST/SVC
Labridae	*Coris julis* (Linnaeus, 1758)	P-Po-R-S	0-24	RST/SVC
	Labrus merula Linnaeus, 1758	R-Po	3.1-24	RST/SVC
	Labrus viridis Linnaeus, 1758	P-Po	0-24	RST/SVC
	Symphodus cinereus (Bonnaterre, 1788)	P-Po-R-S	0-24	RST/SVC
	Symphodus doderleini Jordan, 1891	P-Po-R	0-24	RST/SVC
	Symphodus mediterraneus (Linnaeus, 1758)	P-Po-R-S	0-24	RST/SVC
	Symphodus melanocercus (Risso,1810)	P-Po-R-S	0-24	RST/SVC
	Symphodus ocellatus (Forsskål, 1775)	P-Po-R	0-24	RST/SVC
	Symphodus roissali (Risso, 1810)	P-Po-R-S	0-12	RST/SVC
	Symphodus rostratus (Bloch, 1797)	R-P-Po	0-24	RST/SVC
	Symphodus tinca (Linnaeus, 1758)	P-Po-R	0-24	RST/SVC
	Thalassoma pavo (Linnaeus, 1758)	P-Po-R-S	0-24	RST/SVC
	Xyrichthys novacula (Linnaeus, 1758)	S	0-12	RST/SVC
Mugilidae	*Liza aurata* (Risso, 1810)	S	0-24	RST
	Mugilidae	P-Po-R-S	0-24	RST/SVC
Mullidae	*Mullus barbatus* Linnaeus, 1758	P-R-S	0-12	RST/SVC
	Mullus surmuletus Linnaeus, 1758	P-Po-R-S	0-24	RST/SVC
Muraenidae	*Muraena helena* Linnaeus, 1758	R	3.1-12	RST
Pomacentridae	*Chromis chromis* Linnaeus, 1758	P-Po-R-S	0-24	RST/SVC
Scorpaenidae	*Scorpaena notata* Rafinesque, 1810	P-Po-R	0-24	RST
	Scorpaena porcus Linnaeus, 1758	P-R-S	0-24	RST/SVC
	Scorpaena scrofa Linnaeus, 1758	P-R	0-24	RST/SVC
Serranidae	*Anthias anthias* (Linnaeus, 1758)	R	12.1-24	RST
	Serranus cabrilla (Linnaeus, 1758)	P-Po-R-S	0-24	RST/SVC
	Serranus hepatus (Linnaeus, 1758)	P-S	3.1-24	RST/SVC
	Serranus scriba (Linnaeus, 1758)	P-Po-R	0-24	RST/SVC
Soleidae	*Solea* sp.	S	0-12	RST

Table I. - Continued. *[Suite.]*

Family	Taxa	Substrate types	Depth range (m)	Visual Census Method
Sparidae	*Boops boops* (Linnaeus, 1758)	P-Po-R-S	0-24	RST/SVC
	Dentex dentex (Linnaeus, 1758)	P-Po-R	0-24	RST/SVC
	Diplodus annularis (Linnaeus, 1758)	P-Po-R-S	0-24	RST/SVC
	Diplodus puntazzo (Cetti, 1789)	P-Po-R	0-24	RST/SVC
	Diplodus sargus (Linnaeus, 1758)	P-Po-R-S	0-24	RST/SVC
	Diplodus vulgaris Geoffroy Saint-Hilaire, 1817	P-Po-R-S	0-24	RST/SVC
	Lithognathus mormyrus (Linnaeus, 1758)	S	0-24	RST/SVC
	Oblada melanura (Linnaeus, 1758)	P-Po-R-S	0-24	RST/SVC
	Pagellus acarne (Risso, 1826)	S	0-3	RST
	Pagellus erithrynus (Linnaeus, 1758)	P-R-S	0-24	RST/SVC
	Pagrus pagrus (Linnaeus, 1758)	P-Po-R-S	0-24	RST/SVC
	Sarpa salpa (Linnaeus, 1758)	P-Po-R	0-24	RST/SVC
	Sparus aurata Linnaeus, 1758	P-Po-R	0-12	RST/SVC
	Spondyliosoma cantharus (Linnaeus, 1758)	P-Po-R-S	0-24	RST/SVC
Syngnatidae	Syngnatidae	R	12.1-24	SVC
Synodontidae	*Synodus saurus* (Linnaeus, 1758)	R-P-S	0-12	RST
Trachinidae	*Trachinus draco* Linnaeus, 1758	S	0-24	RST/SVC
Triglidae	*Trigla lucerna* Linnaeus, 1758	S	3.1-24	RST/SVC
Tripterygiidae	*Tripterygion tripteronotus* (Risso,1810)	P-R	0-12	RST/SVC

Table II. - Number of taxa associated to the considered substrate types. *[Nombre de taxons observés pour les types de substrats considérés.]*

	Substrate type			
Taxa	*P. oceanica*	Rocky	Pebble	Sand
Exclusive	0	14	0	11
Total number	33	57	43	36
Shared between pair of substrate types	32 32 40 19 26 25			
Shared among all substrate types	19			
Total number	68			

Diversity

Figure 2 shows the Shannon-Weaver Index calculated using SVC mean fish abundances *per* depth range and substrate type. Fish assemblages associated with rocky bottom within the 0-3 m depth range showed the highest values of H', whereas the lowest values were always recorded over sand. Shannon-Weaver Index value decreased with depth over rocky bottom, while remained unchanged over pebble, *P. oceanica* and sand. The analysis of variance performed on the Shannon-Weaver Index showed a significant difference only among substrate types (Tab. III), and post-hoc analysis (Tukey Test) showed that H' value for the fish assemblage over sand was significantly lower than those calculated for the other three substrate types.

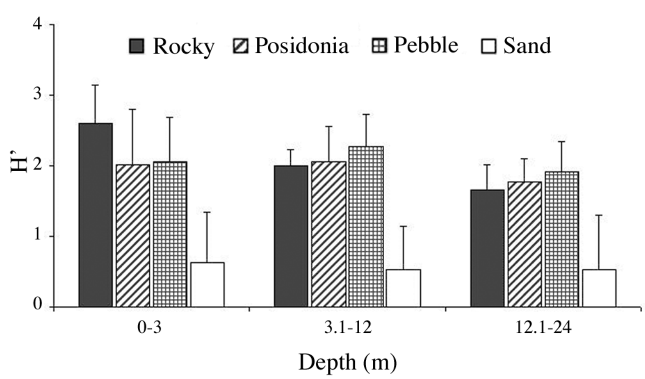

Figure 2. - Shannon-Weaver Index (H') on stationary visual census (SVC) mean fish abundances per depth range and substrate type. Bars = standard deviations. *[Index de Shannon-Weaver (H') calculé sur l'abondance moyenne des poissons, relevée par SVC, selon la profondeur et le type de substrat. Barres = déviation standard.]*

Mean abundances

Figure 3 shows the mean abundances *per* substrate type and depth for the whole fish assemblage (Fig. 3A), and excluding the gregarious-planktivorous species (Fig. 3B). Abundances were highest on rocky bottom and lowest on sand (Fig. 3A, 3B). Mean fish abundance values were inde-

Table III. - Results of ANOVA on Shannon-Weaver index of the whole fish assemblage for effects of substrate type and depth. P = pebble; Po = *P. oceanica*; R = rocky; S = sand. *[Résultats de l'ANOVA sur l'index Shannon-Weaver calculé sur le peuplement total en prenant en considération le type de substrat et la profondeur. P = galets ; Po =* P. oceanica *; R = roche ; S = sable.]*

Source of variation	df	MS	*F*-values	*p*	Tukey (p < 0.05)
Substrate	3	10.69	35.61	< 0.001	R = Po = P > S
Depth	2	0.86	2.88	NS	
Substrate/Depth	6	0.29	0.98	NS	
Residual	60	0.30			
Total	71				

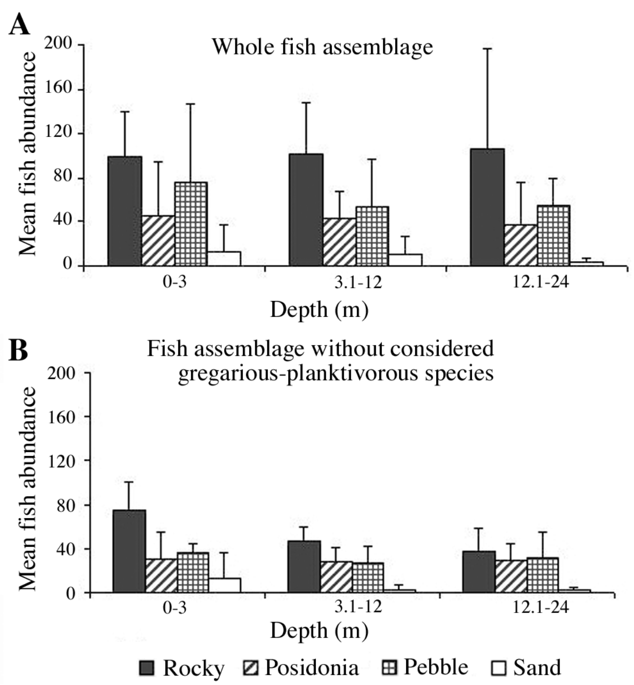

Figure 3. - Mean abundance of the fish assemblage as a whole (**A**), and without the considered gregarious-planktivorous species component (**B**) *per* depth range and substrate type. Bars = standard deviations. *[Abondance moyenne du peuplement total de poissons (**A**) et sans les espèces grégaires-planctonophages (**B**), selon la profondeur et le type de substrat. Barres = déviation standard.]*

pendent of depth on rocky bottom and *P. oceanica*, while over pebble and sand, they decreased slightly with depth (Fig. 3A). Excluding gregarious-planktivorous species the mean fish abundance decreased with increasing depth over rocky bottom and sand, but did not show any particular trend over *P. oceanica* and pebble (Fig. 3B).

Analyses of variance performed on mean fish abundance *per* 78.5 m^2 for the entire fish assemblage showed a significant difference among substrates only (Tab. IVA), while, excluding gregarious-planktivorous species, the ANOVA revealed significant differences both among substrate and depth ranges (Tab. IVB). Post-hoc analysis (Tukey test) showed that higher mean abundance values were recorded

Table IV. - Results of ANOVAs testing for substrate type and depth range in log transformed mean fish abundance (mean number of individuals per 78.5 m^2), taking into account the whole fish assemblage (**A**) and the fish assemblage excluding the considered gregarious-planktivorous species (**B**). P = pebble; Po = *P. oceanica*; R = rocky; S = sand. *[Résultats de l'ANOVA calculés sur l'abondance moyenne des poissons (nombre moyen d'individus pour 78,5 m^2 converti en valeur logarithmique) en fonction de la profondeur et du type de substrat pour le peuplement total de poissons (**A**), en excluant les espèces grégaires-planctonophages (**B**). P = galets ; Po =* P. oceanica *; R = roche ; S = sable.]*

Source of variation	df	MS	*F*-values	*p*	Tukey (p < 0.05)
Substrate	3	6.28	44.24	< 0.001	R ≥ P ≥ Po > S
Depth	2	0.03	0.21	NS	
Substrate/Depth	6	0.04	0.32	NS	
Residual	60	0.14			
Total	71				

A

Source of variation	df	MS	*F*-values	*p*	Tukey (p < 0.05)
Substrate	3	4.71	50.35	< 0.001	R ≥ P ≥ Po > S
Depth	2	0.35	3.76	< 0.05	0-3 ≥ 3-12 > 12-24
Substrate/Depth	6	0.11	1.18	NS	
Residual	60	0.09			
Total	71				

B

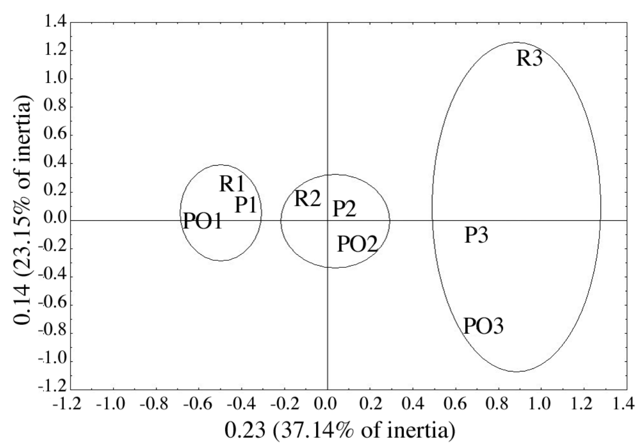

Figure 4. - Ordination of the strata points on the first two axes given by the correspondance analysis (CA) on stationary visual census (SVC) mean abundance data excluding sand data set and the gregarious-planktivorous species. P1 = Pebble 0-3 m, P2 = Pebble 3.1-12 m, P3 = Pebble 12.1-24 m; PO1 = *P. oceanica* 0-3 m, PO2 = *P. oceanica* 3.1-12 m, PO3 = *P. oceanica* 12.1-24 m; R1 = rocky bottom 0-3 m, R2 = rocky bottom 3.1-12 m, R3 = rocky bottom 12.1-24 m. *[Ordination des stations sur les deux premiers axes obtenus avec CA sur les données d'abondance moyenne, relevées par SVC, en excluant les données concernant les fonds sableux et les espèces grégaires-planctonophages. P1 = galets, 0-3 m ; P2 = galets, 3,1-12 m ; P3 = galets, 12,1-24 m ; PO1 =* P. oceanica*, 0-3 m ; PO2 =* P. oceanica*, 3,1-12 m ; PO3 =* P. oceanica*, 12,1-24 m ; R1 = fond rocheu,x 0-3 m ; R2 = fond rocheux, 3,1-12 m ; R3 = fond rocheux, 12,1- 24 m.]*

over rocky bottom, followed by pebble and *P. oceanica*, and the lowest values were collected over sand, considering both the whole fish assemblage and excluding gregarious-plank-

tivorous species. Taking into account depth ranges, mean abundance values showed significant difference only for the fish assemblage excluding gregarious-planktivorous species and post-hoc analysis revealed an higher value at the 0-3 m depth range.

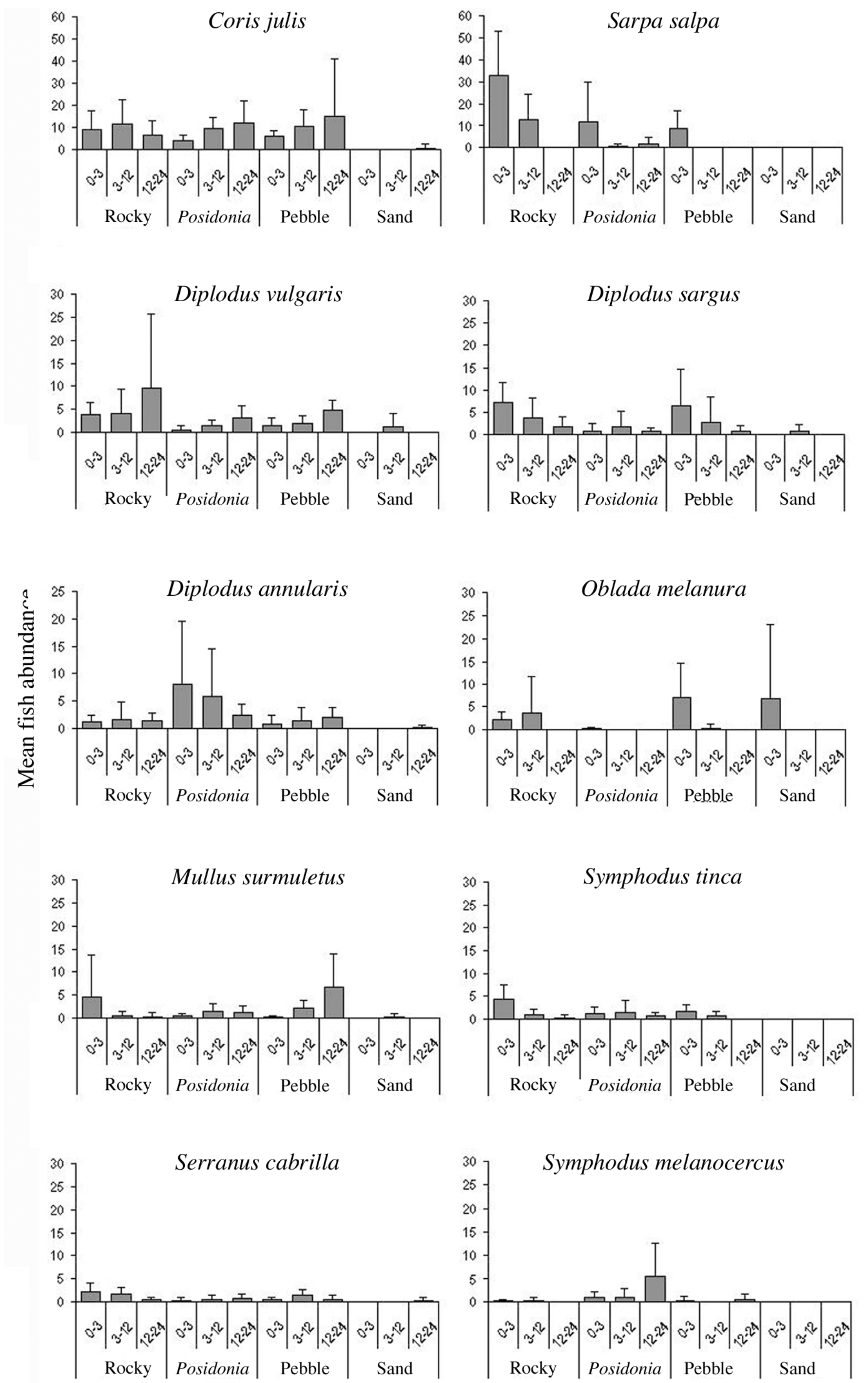

Figure 5. - Mean density of some abundant species *per* depth range and substrate type. Bars = standard deviations. *[Densité moyenne des espèces les plus abondantes selon la profondeur et le type de substrat. Barres = déviation standard].*

Species distribution with reference to depth and substrate type

The CA on mean abundance data excluding the gregarious-planktivorous species indicated a significant difference between the fish fauna recorded over sand, composed of highly exclusive species, and the assemblages associated with the other substrate types. To improve the analysis of these groups of assemblages, a CA was performed excluding the sand data set. The ordination of the strata points along the first two axes clearly discriminated the assemblages on a basis of depth, identifying three main groups (Fig. 4). In the 3-12 m depth range, the assemblage was in a central position, while the deepest depth range had a strong positive abscissa and the shallowest strata, negative. The second axis of the CA placed the strata points belonging to each depth range in the same order: rocky bottom always had the highest ordinate, followed by pebble and *P. oceanica*, with an increase in the variance with the depth (Fig. 4). The fish assemblage over pebble always occupied an intermediate position independent from depth.

Figure 5 shows the mean abundances *per* substrate type and depth for the 10 most abundant nectobenthic species (*Coris julis, Sarpa salpa, Diplodus annularis, D. sargus, D. vulgaris, Oblada melanura, Mullus surmuletus, Symphodus tinca, S. melanocercus* and *Serranus cabrilla*). Analyses of variance performed on mean abundance *per* 78.5 m^2 showed that *S. salpa* was significantly more abundant over rocky bottom ($F = 10.32$, $p < 0.001$) and in the 0-3 m depth range ($F = 14.02$, $p < 0.001$), while the abundance of the labrids *C. julis* and *S. tinca*, and of the seabreams *D. sargus* and *D. vulgaris* were significant over rocky bottom, pebble and *P. oceanica* meadow compared with sand (*C. julis*: $F = 4.29$, $p < 0.01$; *S. tinca*: $F = 10.32$, $p < 0.01$;

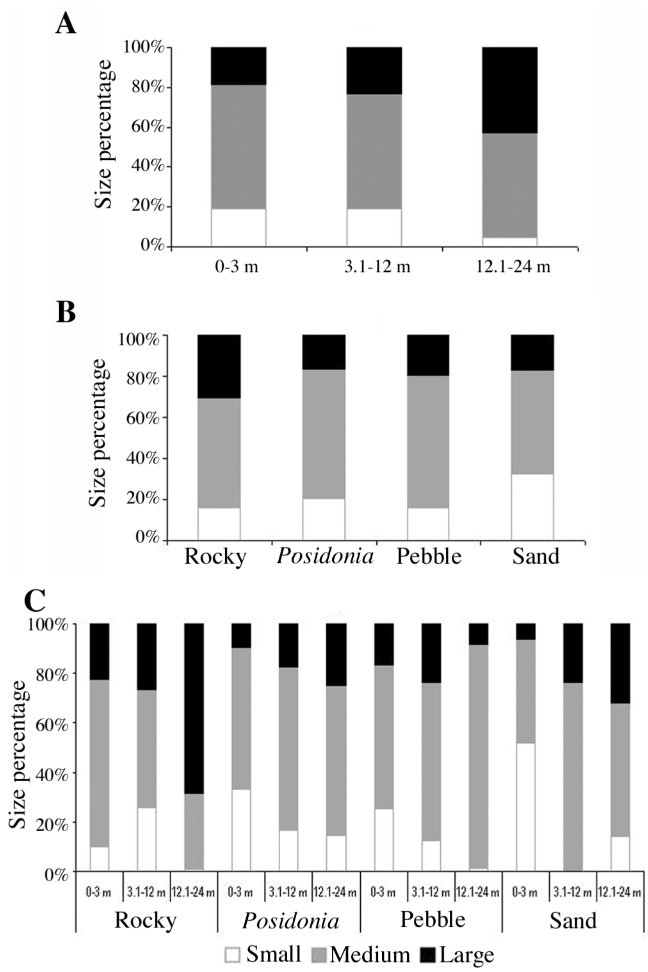

Figure 6. - Fish size classes composition *per* depth range (**A**), substrate type (**B**), and considering both factors (**C**), excluding the gregarious-planktivorous species. *[Répartition des classes de taille des poissons selon la profondeur (**A**), le type de substrat (**B**) et en prenant en considération les deux facteurs (**C**), en excluant les espèces grégaires-planctonophages].*

D. sargus: $F = 4.48$, $p < 0.01$; *D. vulgaris*: $F = 3.59$, $p < 0.05$). The mean abundance values of *D. sargus* and *S. tinca* were significantly higher in the 0-3 m depth range ($F = 3.37$, $p < 0.05$ and $F = 7.02$, $p < 0.01$, respectively) while *D. annularis* ($F = 4.86$, $p < 0.01$) and *S. melanocercus* ($F = 4.18$, $p < 0.01$) were significantly more abundant over *P. oceanica*. *S. cabrilla* was significantly more abundant over rocky bottom and pebble ($F = 6.37$, $p < 0.001$), while *O. melanura*, commonly present over rocky bottom, pebble and sand, was significantly more abundant in the 0-3 m and 3.1-12 m depth ranges ($F = 3.25$, $p < 0.05$).

Demographic patterns

The medium size class of fish was the most abundant (56% of the whole fish assemblage), followed by large (27.5%) and small (16.5%) fish. The medium size class predominated in all depth ranges (Fig. 6A) and substrate types (Fig. 6B). The prevalence of the small and the large size class occurred in the 0-3 m depth range over sand and the 12.1-24 m depth range over rocky bottom respectively (Fig. 6C). Taking into account the proportions of small, medium and large fish associated to each substrate type, the analyses showed significant differences between the 3.1-12 m and 12.1-24 m depth range over rocky bottom (χ^2, $p < 0.05$), and between the 0-3 m and the 3.1-12 m depth range over sand (χ^2, $p < 0.001$).

DISCUSSION

The taxonomic composition of fishes studied in the waters of Portofino Promontory was found to have a slightly higher number of species compared with that reported in other studies using both the same techniques (Tunesi and Salvati, 2002; Molinari and Tunesi, 2003) and other visual census method (Harmelin *et al*., 1995; Letourneur *et al*., 2003) in the NW Mediterranean Sea and in Adriatic Sea (Guidetti, 2000; Lipej *et al*., 2003) This may be partly due to the presence of some cryptic fish species with strictly benthic habits.

Depth is a key factor affecting the structure of fish assemblages (Bell, 1983). Many fish species will prefer a particular set of environmental characteristics that may be found at a particular depth. In this study, only 53% of the species were recorded at all bathymetric ranges. In particular, the data on species composition highlighted the importance of the 0-3 m depth range for many fish species and revealed a strong contribution of the shallow dwelling Blenniidae to biodiversity (Goren and Galil, 2001). With regard to substrate type, the diversity index was higher for the fish assemblage associated with rocky bottom, pebble and *P. oceanica* meadow, than those associated with sand. These results clearly indicate that diversity in fish assemblages is highest in shallow habitats as well as in more structurally complex substrate types. The fish assemblage associated with pebble did not show any exclusive species, and appeared more similar to those associated with rocky bottom and to *P. oceanica* than to sand. This result could be due to the nature of this substrate, characterised by flat pebble which is unsuitable as habitat for most sand species due to their burrowing behaviour.

The fish assemblage associated with rocky bottom showed higher mean abundance values in all the depth ranges, while the lowest values were associated with sand and *P. oceanica* meadow; fish assemblages over pebble showed intermediate values. These results support the hypothesis that the substrate is *per* se one of the main factors affecting coastal fish assemblages (Guidetti, 2000).

The higher abundance on rocky bottom and pebble of herbivorous, such as *Sarpa salpa*, omnivorous, such as *D.*

sargus, D. vulgaris, C. julis and *S. tinca*, and carnivorous fish, such as *S. cabrilla*, could be mainly a result of food availability (Lejeune, 1985; Fischer *et al.*, 1987; Verlaque, 1990; Sala and Ballestreros, 1997): actually these substrates showed rich and diverse phytobenthos in the investigated area (Morri *et al.*, 1986), on which they feed and find prey. The preference of *D. annularis* and *S. melanocercus* for habitat characterised by *P. oceanica* beds is consistent with the literature (Michel *et al.*, 1987; Tunesi *et al.*, 1997).

The role of the fish assemblage associated to shallower rocky bottoms becomes more relevant with regard to the necto-benthic component, which is generally affected by the substrate type. Recorded data also support previous results obtained in studies conducted by Bell (1983) at Port-Cros (France), showing an increasing of gregarious-planktivorous species with depth.

According to a CA, the main factor affecting fish composition in the investigated area seemed to be the significant difference between the assemblages associated to sand and the other substrate types. This result, based essentially on the presence of many exclusive species over sand, agrees with previous observations on the clear separation between fish assemblages associated with sand and other habitats (Ferrell and Bell, 1991; Guidetti, 2000). When data for sand and gregarious-planktivorous species were excluded, depth was the main factor accounting for variability among fish assemblages. These results are consistent with the differences previously shown between the fish fauna associated with shallow (0-10 m depth) and deep seagrass meadows (> 10 m) (Harmelin-Vivien, 1983; Francour, 1997) and also those related to depth in rocky reef fish assemblages (Garcia-Charton and Pérez-Ruzafa, 1998). The data further suggested that pebble fish assemblages constantly showed an intermediate composition at the three investigated depth ranges with respect to those associated to other two substrate types. There was also a progressive diversification of *P. oceanica* and rocky bottom fish assemblages with depth, which was greatest in the deepest depth range.

The size data collected generally highlighted the dominance of medium size class fish, indicating differences in size composition with depth. In particular, the 0-3 m depth range showed the highest percentage of small fish, confirming the general importance of shallow waters for juveniles (Tunesi *et al.*, 1997; Planes *et al.*, 1998; Letourneur *et al.*, 2003). Large specimens appeared to be in general more abundant in depths greater than 3 m.

The results of this study emphasized significant differences among fish assemblages associated with depth range and substrate type. These results suggest that these factors should be considered in planning future studies, especially for those relating to fish fauna of coastal areas to be included in marine protected areas. Special care could be devoted to studying the 0-3 m depth range, which is poorly investigated in general, both for the presence of many exclusive species (eg. Blennies) and as the most important range for juveniles, especially over sand and pebble.

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